NEOTROPICAL
BIOLOGY AND CONSERVATION

Neotropical Biology and Conservation
16(2): 351–367 (2021)
doi: 10.3897/neotropical.16.e63414

RESEARCH ARTICLE

Success in conserving the bird diversity in tropical forests through private protected areas in Western Ecuador

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Academic editor: A.M. Leal-Zanchet | Received 28 January 2021 | Accepted 13 May 2021 | Published 27 May 2021

Citation: Guerrero-Casado J, Seoane JM, Aguirre N, Torres-Porras J (2021) Success in conserving the bird diversity in tropical forests through private protected areas in Western Ecuador. Neotropical Biology and Conservation 16(2): 351–367. https://doi.org/10.3897/neotropical.16.e63414

Abstract

Private protected areas have recently attained more importance at a worldwide level as regards nature conservation. Particularly, the specific region of Western Ecuador receives hardly any protection from the State, and private reserves could, therefore, be a suitable tool to ensure the preservation of its forests and their associated wildlife biodiversity. In this work, we compare the bird species richness between private reserves and public protected areas (managed by the State) located in this region. We also show a checklist of bird species found in the Buenaventura Reserve, a private reserve located in south-western Ecuador. Our comparison shows that smaller private reserves may harbour a similar number

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of bird species than larger protected areas managed by the state, and they have a higher number of bird species per area. In particular, a total of 233 different bird species were registered in Buenaventura, which were distributed in 16 orders and 42 families. Three species were classified as endangered at an international level: El Oro Parakeet (*Pyrrhura orcesi*), El Oro Tapaculo (*Scytalopus robbinsi*), and the Grey-backed Hawk (*Pseudastur occidentalis*), and another three at a national level: the Long-wattled Umbrellabird (*Cephalopterus penduliger*), the Slaty-winged Foliage-gleaner (*Philydor fuscipenne*), and the White-vented Plumeleteer (*Chalybura buffonii*). Therefore, private reserves can be appreciated as a suitable conservation tool for bird conservation, and they should not be undervalued because of their smaller size. Buenaventura Reserve is a good example of how private reserves are extremely important in fragmented landscapes, as is the case with tropical forests in Western Ecuador.

Keywords
Avian diversity, biodiversity conservation, cloud forest, private reserves, protected areas, species richness, wildlife conservation

Introduction

A private protected area (hereafter PPA) is a protected area under private governance, managed by a variety of private actors, such as nongovernmental organisations (NGOs), commercial companies, or researcher entities with the aim to achieve biodiversity conservation objectives (Capano et al. 2019; Palfrey et al. 2020). According to the IUCN, private governance comprises protected areas under individual, cooperative, NGO or corporate control and/or ownership, and managed under not-for-profit or for-profit schemes (Dudley 2008). Although the establishment of PPAs is considered a good conservation measure by which to complement the conservation efforts made by the public administrations (Roldán et al. 2010; Hora et al. 2018), PPAs are often unrecognised by governments, and most of them are not included in the World Database on Protected Areas (Dudley 2008). Moreover, the scientific literature and research efforts have been more frequently focused on larger public protected areas (Capano et al. 2019).

Nevertheless, PPAs can be an extremely useful tool to achieve global conservation goals, because public protected areas (PAs) are insufficient to reduce the global biodiversity crisis (Kamal et al. 2015). Although PPAs mostly do not cover large areas, they can increase the total area under protection and enhance landscape connectivity, and have additional socio-economic benefits, thus reducing social conflicts (Stolton et al. 2014; Capano et al. 2019). For instance, Shanee et al. (2017) showed that many threatened vertebrate species would lack protection without the presence of the private or communal protected areas in Peru, and they argue that PPAs is the best option in small areas located in densely populated areas where species with a restrictive range occur. As a consequence, a growing recognition of the conservation benefits of private reserves has favoured the proliferation of PPAs worldwide, and some countries have integrated PPAs into their national protected area systems (Dudley 2008; Pasquini et al. 2011; Stolton et al. 2014).

This is the case in Ecuador, where private protected areas are considered a subsystem of the National Protected Areas Network (Sistema Nacional de Áreas Protegidas, SNAP, in Spanish), although some of them are not officially included in this national network (Ministerio del Ambiente del Ecuador 2009). The Heritage of Natural Areas of the Ecuadorian State (Patrimonio de Areas Naturales del Estado, PANE, in Spanish) is another subsystem of the SNAP managed by the State, and comprises 48 units that cover almost 20% of the country (Cuesta et al. 2017). This would, however, appear to be insufficient, since some ecosystems are underrepresented in the national network and the high risk of ecosystem conversion, thus suggesting the need to detect and create new priority areas for biodiversity conservation (Sierra et al. 2002; Lessmann et al. 2014; Cuesta et al. 2017). This topic is particularly relevant in the western region of Ecuador (which extends from the Pacific Ocean to the western slope of the Andes), because the protected areas managed by the State (PANE) only cover 5% of its surface (Cuesta et al. 2017). This region is considered a biodiversity hotspot owing to its exceptional concentrations of endemic species (Myers et al. 2000), but it has been intensively deforested since the middle of the 20th century, and some authors have estimated that less than 20–30% of the original forest remains undisturbed (Dodson and Gentry 1991; Sierra 2013). Indeed, the IUCN Red List of Ecosystem criteria classifies the two main vegetation biomes, humid forest and seasonal dry forest, as critically endangered (CR) at an international level (Ferrer-Paris et al. 2019). Moreover, at a national level, some of the ecosystems of Western Ecuador are the most threatened and the least protected in the country (Sierra et al. 2002; Rivas et al. 2020).

This strip is, therefore, of particular importance in Western Ecuador (Garzón-Santomaro et al. 2019), and these remaining forests are consequently considered a Priority Area for the Conservation of Biodiversity (Cuesta et al. 2017), where PPAs can play an important role. Several non-governmental organisations (NGOs) manage many natural areas in the country, as is the case with the Jocotoco Foundation (www.jocotoco.org), which acquires strategic land and manages it as biological reserves. One of these private reserves is the Buenaventura Reserve, located in southwestern Ecuador (Fig. 1), which is considered one of the best preserve forests in the zone since, outside the reserve, mostly only forest patches smaller than 100 ha remain as the result of intense deforestation (Hermes et al. 2016). In spite of its conservation importance in the region and it being catalogued as an Important Bird Area (Code EC071; BirdLife International 2020), an updated checklist of the bird species inhabiting the Buenaventura Reserve that is based on scientific data is not yet available. Moreover, the importance of PPAs for wildlife conservation in Western Ecuador has been poorly explored. The objectives of this work are, therefore, i) comparing the bird species richness registered between the public (PA) and private (PPA) protected areas, and ii) to assess the bird species richness in the Buenaventura Reserve, with the final goal of highlighting the important role played by private reserves as regards bird conservation in Western Ecuador.

Materials and methods

Study area

Data concerning bird species richness were collected in PAs and PPAs (see below) located in Western Ecuador, including the Coastal Region, the Western slope of the Andes, and the southern region of Ecuador (Fig. 1). This region has been strongly deforested, which has entailed a significant loss of biodiversity (Dodson and Gentry 1991), although the remaining native forests may still harbour a high level of biodiversity (e.g. Zambrano et al. 2019; Solórzano et al. 2021). For instance, 183 of the species of mammals, representing 42% of the total number of national mammal species, can be found in Western Ecuador (Tirira 2017). In the case of birds, the Chocó humid region and the Equatorial Pacific dry region harbour more than 450 and 250 bird species, respectively, with an important proportion of regional endemism (Bioweb 2020). This region has a high-altitude gradient extending from sea level to the Andean moors. The maximum richness of bird species on the slope occurs in the Piedmont biome at altitudes between 400 and 1,600 metres.

The fieldwork was performed in the Buenaventura Reserve, which is located on the western slope of the Ecuadorian Andes in the south of the country, in the province of El Oro (Fig. 1). This private reserve was created in 1999 and originally covered 400 ha, but it has been expanded up to almost 3,000 hectares, with an altitude range of between 400 and 1,500 m.a.s.l. During fieldwork carried out in this study, the reserve had approximately 2,300 ha. The Jocotoco Foundation, which manages this reserve, has carried out conservation and reforestation works after purchasing local farms, which were previously inhabited by livestock (https://www.jocotoco.org/wb#/ES/Buenaventura). The lowlands of the reserve include recovered Tumbes forests, but the majority are formed of cloud forest (Torres-Porras et al. 2017), which is one of the most extensive patches of cloud forest in the western foothills of the Andes in south-western Ecuador. It is important to highlight that these forests are secondary forests in various successional stages (Hermes et al. 2016). Its good conservation status has led to the realisation of several scientific studies in the reserve in the last few years in order to assess its biodiversity (e.g. Cogălniceanu et al. 2015; Hermes et al. 2016, 2018a, b; Székely et al. 2016; Torres-Porras et al. 2017; Betancourt et al. 2018).

Avian diversity in private and public protected areas

The number of bird species recorded in PAs and PPAs located in Western Ecuador was sought in scientific literature, reports and in the Important Bird Areas (IBAs) webpage (http://datazone.birdlife.org). Although the methodology and sampling can vary among places, this rough comparison is useful to compare the avian diversity of PPAs and PAs. We collected literature values for the avian species richness of 8 PAs (including a bird census performed in Cerro San Sebastian in Machalilla National Park; – Dustin and Ágreda (2005)) and 14 PPAs of the Western Ecuador (Fig. 1), ex-

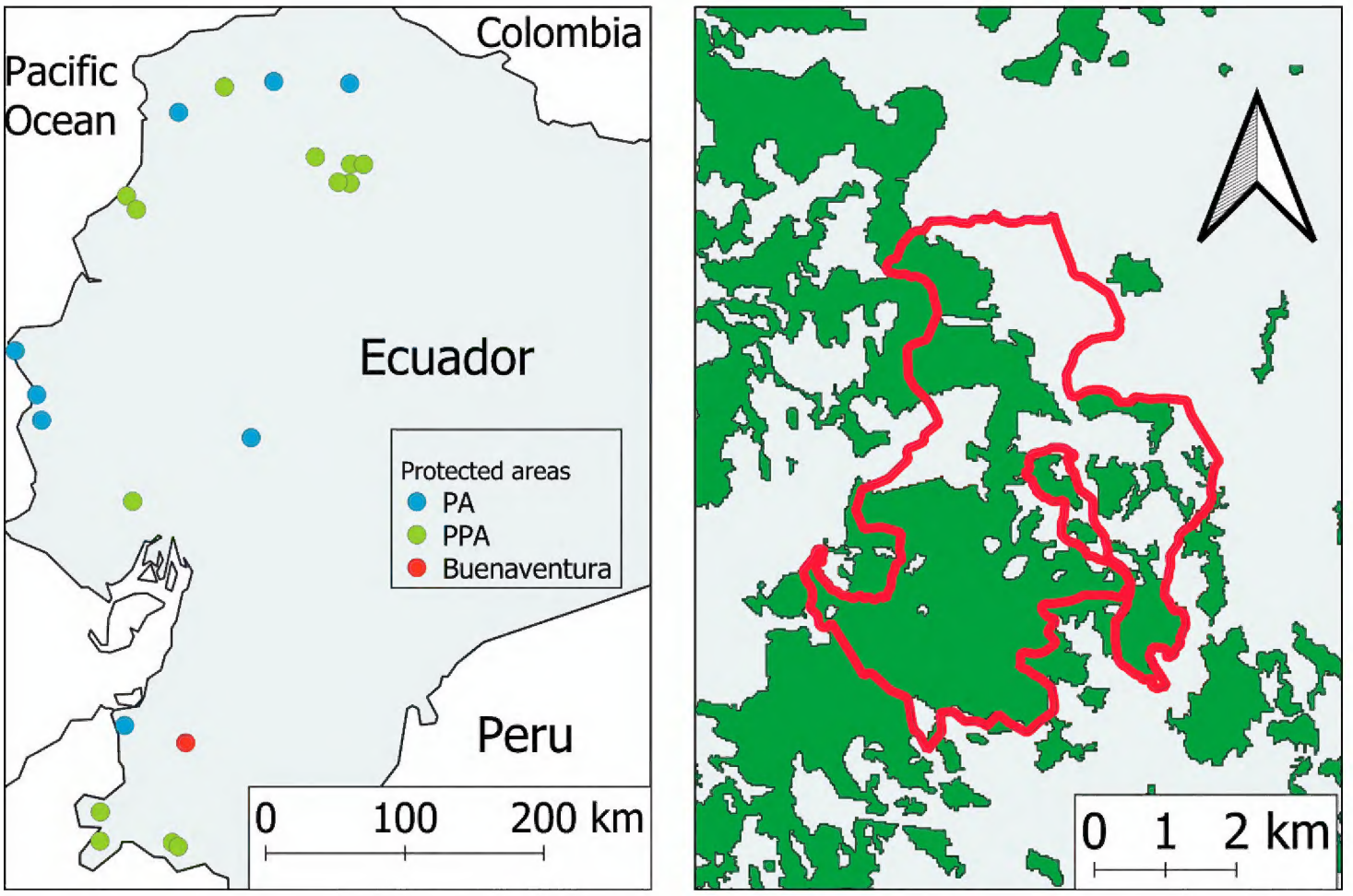


Figure 1. The location of the public protected areas (PA-blue spots) and private protected areas (PPA-green spots) in Western Ecuador used in this study to compare bird species richness between them. The location of the Buenaventura Reserve in Ecuador is illustrated by a red spot. The figure on the right shows the limits of Buenaventura Reserve (red line), showing the remaining native forests (green polygons), obtained from the land use cover of the Environment Ministry of Ecuador in 2018 (available at http://ide.ambiente.gob.ec/mapainteractivo/).

cluding those protected areas located exclusively in coastal zones (e.g., mangroves). The number of bird species every 100 ha was also calculated to standardise the number of bird species according to the size of the PAs and PPAs (Formula 1).

$$Bird\ species\ richness\ per\ area = \frac{N^{\circ}\ of\ bird\ species}{Protected\ area\ size\,(ha)} \times 100$$

Moreover, we obtained the trigger species list of six Important Bird Areas (IBAs) almost fully located in protected areas to compare these bird trigger species in relation to the protected area size and the international threat category according to the IUCN Red List; three of these IBAs overlap with PAs (codes EC008, EC017, and EC037) and three overlap with PPAs (codes EC012, EC026 and EC071) (BirdLife International 2020). We estimated the total number of different bird species in the three PAs and the three PPAs separately, and we also estimated the proportion of species included in one of the threatened categories of the Red List (Critically Endangered -CR-, Endangered -EN- and Vulnerable -VU-) in the three PAs and PPAs separately. This analysis allowed us to compare the composition of key species (globally threatened species, and restrictive-range or biome-restricted species) between PAs and PPAs.

Bird census in Buenaventura Reserve

A bird census in the Buenaventura Reserve was performed by the same two people (JTP and JMS), who identified the birds using binoculars and a camera. Birds were identified on the basis of the authors' experience and checked using field guides of birds of Ecuador (Ridgely and Greenfield 2001; McMullan and Navarrete 2013). The nomenclature was established according to del Hoyo et al. (2015) and the Red List of the Birds of Ecuador (Freile et al. 2019), which was also used to assign the national threat category. The bird census was carried out over four different dates: July-August 2014, January-February 2015, January-February 2016 and June-July 2016.

Three different methodologies were combined with the aim of registering as many species as possible. Firstly, five different fixed transects of 1-km in length were repeated on the four dates in question, and birds were recorded along the transects and for 10 minutes at 4 fixed points separated by 200 m (Martínez and Rechberger 2007; Esquivel and Peris 2008; Politi et al. 2012). Each transect was repeated 9–11 times during the four dates, adding up to a total of 48 transects. Secondly, 53 non-repeated transects of 1-km in length that were randomly located in the reserve were also performed. Both types of transects were sampled a few hours after sunrise and a few hours before dusk, and any visually detected birds were recorded. Thirdly, any birds observed using the nectar artificial feeders were also recorded for 37 days, since some species of hummingbird can be more easily found at these feeders. Finally, some casual encounters with birds not obtained using the three aforementioned methodologies were also considered in order to complete the list of bird species.

Statistical analysis

We evaluated the sampling effort of the bird census performed in Buenaventura by employing a species accumulation curve. The estimated species richness was, meanwhile, estimated on the basis of the Chao 1 richness estimators in EstimateS 9.1 (Colwell 2013) by carrying out 100 runs of randomisations and the classic formula for Chao 1. Although the species accumulation curve did not attain an asymptote, this study recorded 87.7% of the species richness predicted by the Chao-1 estimator (n = 263.43) (Fig. 2). Mann-Whitney *U*-tests were employed to check differences between PAs and PPAs (independent variable) with respect to the bird species richness and the number of bird species per area (response variables).

Results

Comparison of the bird species richness between PPAs and PAs

The fourteen PPAs covered an area of 43,818 ha (mean = 3,129 ha, min 150 – max 10,200 ha), whereas the eight PAs covered an area of 446,299 ha (mean = 47,384 ha, min 1950 – max 243,683 ha). The PPAs have a median of 214 bird species (min 43 – max 401) and 13.52 bird species richness per 100 ha, whereas PAs have a me-

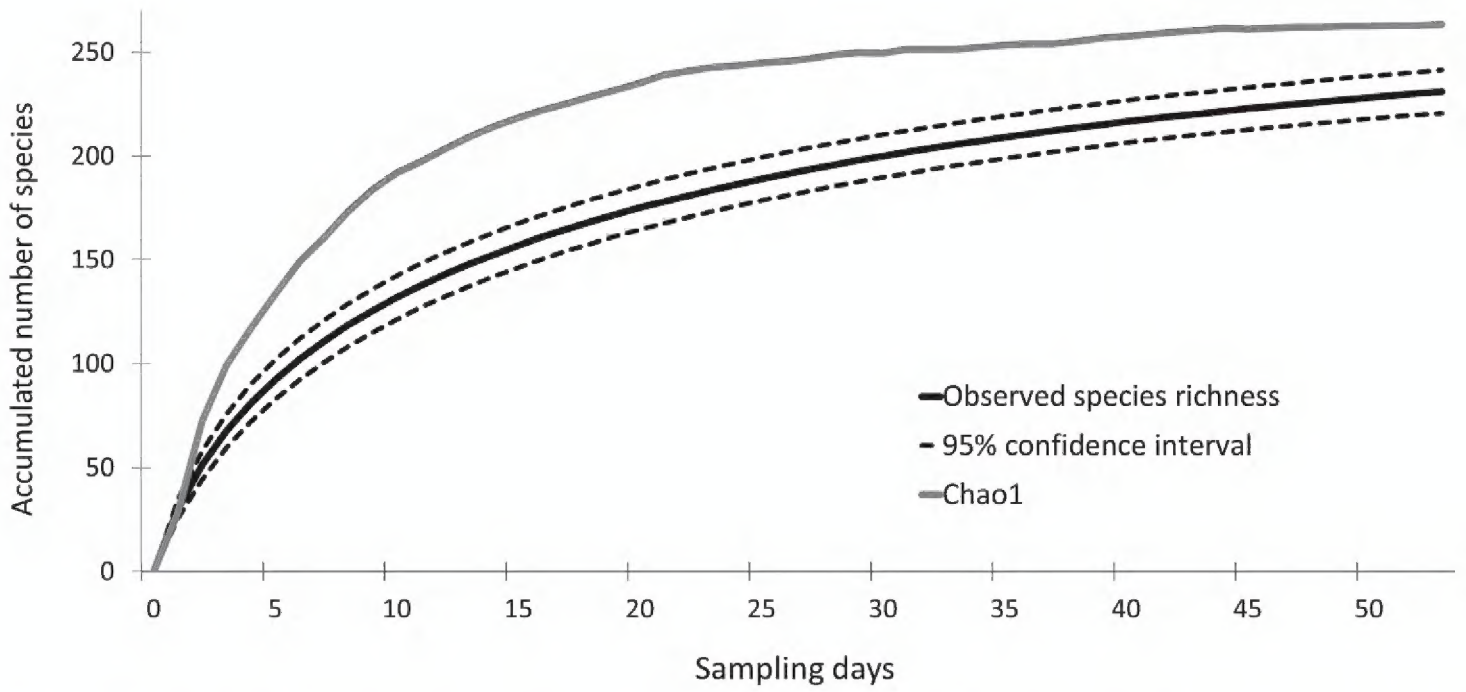


Figure 2. Species accumulation curve (± 95% confidence interval) and Chao-1 estimator of bird species richness in Buenaventura Reserve, Ecuador.

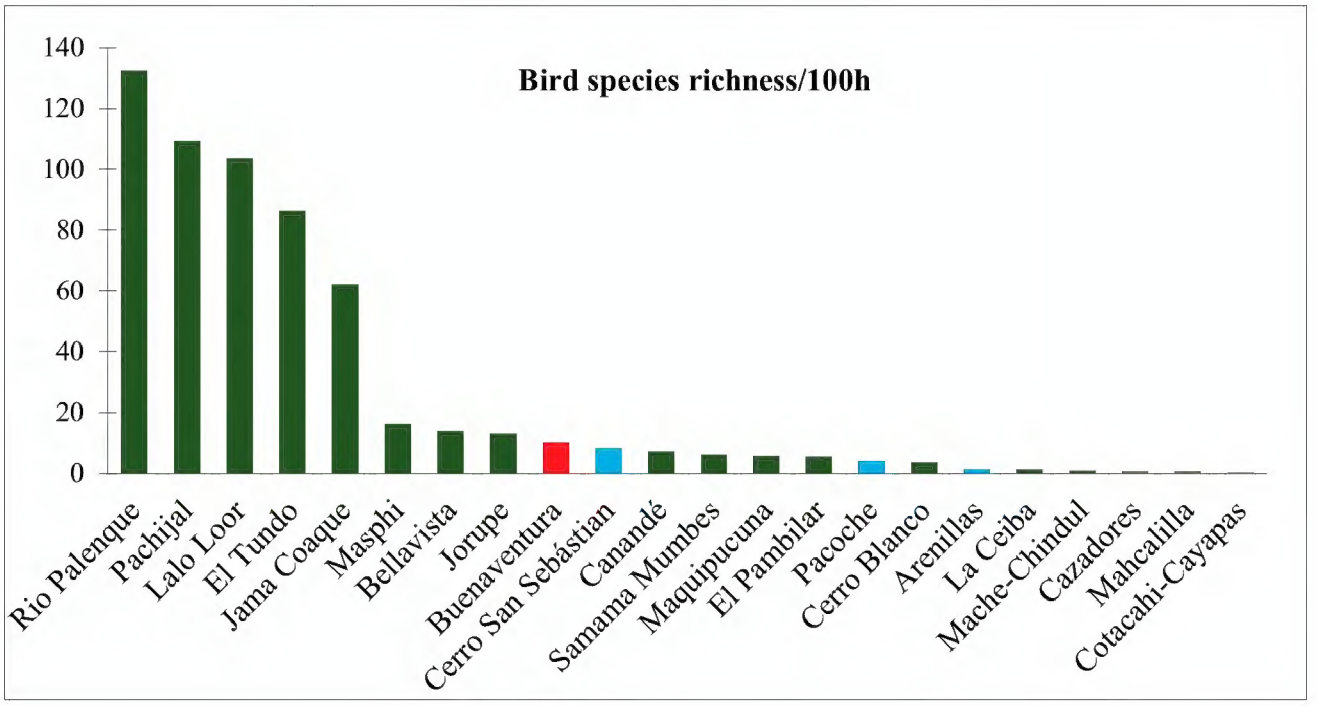
dian value of 186 (min 132 – max 186) and 2.59, respectively (Fig. 3). According to the Mann-Whitney *U*-tests, there was no significant difference between the bird species richness in PPAs and PAs ($U = 55$; $p = 0.945$), but significant differences were found between PPAs and PAs with respect to bird species richness per 100 ha ($U = 18$; $p = 0.0095$).

Concerning the trigger species of the IBAs, the three selected PAs harbour 97 different bird species in 525,269 ha, whereas the three PPAs harbour 52 different bird species in 8,667 ha, which means 0.018 and 0.599 bird species/100 ha respectively. The PAs had 21 different species (representing the 24.65% of their trigger species) included in one of the threat categories (CR+EN+VU), whereas the PPAs had 16 species representing the 30.77% of their trigger species. Six trigger species are located in the three IBAs-PPAs but not in IBAs-PAs: *Pyrrhura orcesi*, *Scytalopus robbinsi*, *Ara ambiguus*, *Basileuterus trifasciatus*, *Cyanocorax mystacalis* and *Glaucidium nubicola*.

Bird species richness recorded in Buenaventura

After pooling all the methodologies together, a total of 2,603 encounters, 5,635 individuals and 233 different species were recorded during the fieldwork in Buenaventura Reserve (see Suppl. material 1: Appendix S1). The species were distributed in 16 orders and 42 families, with the orders with most species being Passeriformes (150), Apodiformes (24), Accipitriformes (13) and Piciformes (13) (Fig. 4). Of the Passeriformes, the Thraupidae, Tyrannidae and Furnariidae families were those with most species (Fig. 4).

Of the 233 species, 222 were recorded during the transects (repeated and non-repeated transects), 10 species were observed at the artificial nectar feeders, and 93 species were observed as a result of casual encounters (Fig. 5).



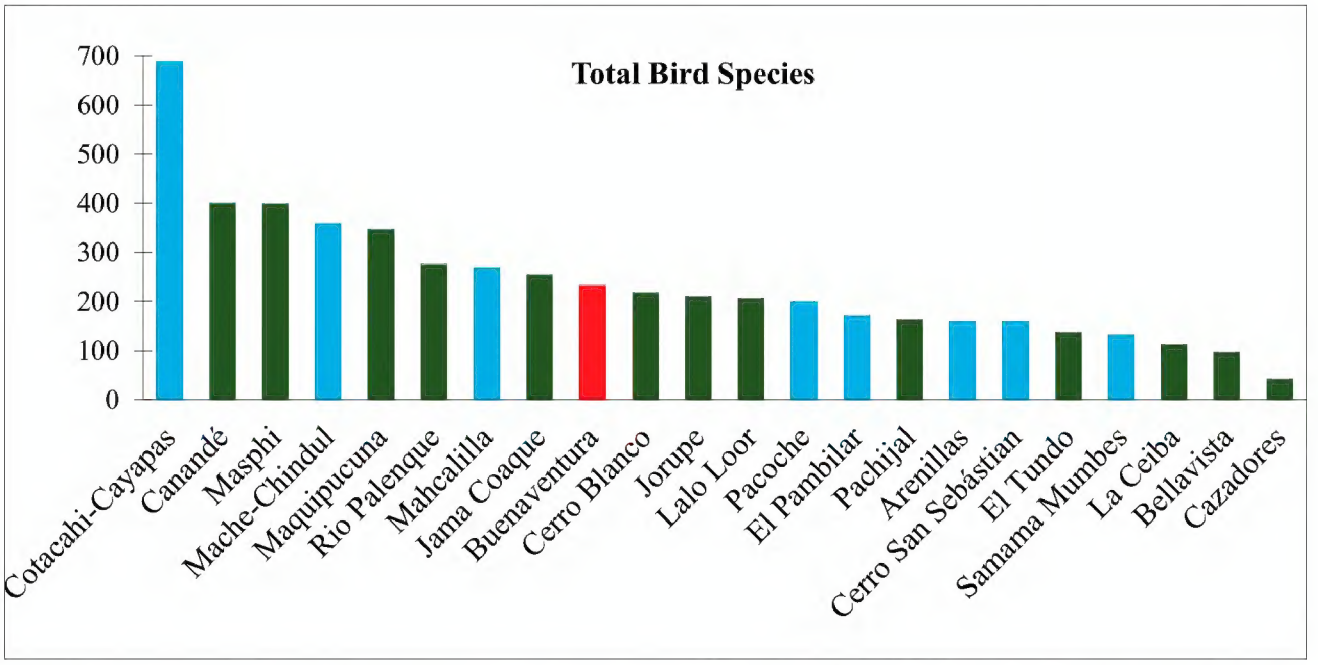


Figure 3. Total bird species richness and the bird species per 100 ha in 22 different places in Western Ecuador. Green = private protected areas (PPA); blue = public protected areas (PA) including in the PANE; red = Buenaventura Reserve according to the data obtained in this study. References: Cotacahi-Cayapas, Pacoche, El Pampilar, Arenillas and Samama Mumbes – http://areasprotegidas.ambiente.gob.ec; Jama Coaque – https://earthmind.org; Masphi – https://www.mashpilodge.com; Machalilla, El Tundo and Milpe – http://datazone.birdlife.org; Cerro San Sebastián – Dustin and Ágreda (2005); Maquipucuna – O'Dea et al. (2006); Cerro Blanco – Mischler (2012); Mache-Chindul – Carrasco et al. (2013); Bellavista – https://www.bellavistacloudforest.com; Pachijal – http://www.reservapachijal.com; Lalo Loor – https://ceiba.org; Jarupe and Canandé – https://www.jocotoco.org; La Ceiba and Cazaderos – Ordóñez-Delgado et al. (2016).

A large proportion (84.9%) of the species were classified as Least Concern (LC), and only 5.4% were classified as threatened (VU and EN). The three species classified as endangered (EN) according to the IUCN Red List of Threatened Species were El Oro Parakeet (*Pyrrhura orcesi*), El Oro Tapaculo (*Scytalopus robbinsi*) and the Grey-backed Hawk (*Pseudastur occidentalis*). Three species are considered en-

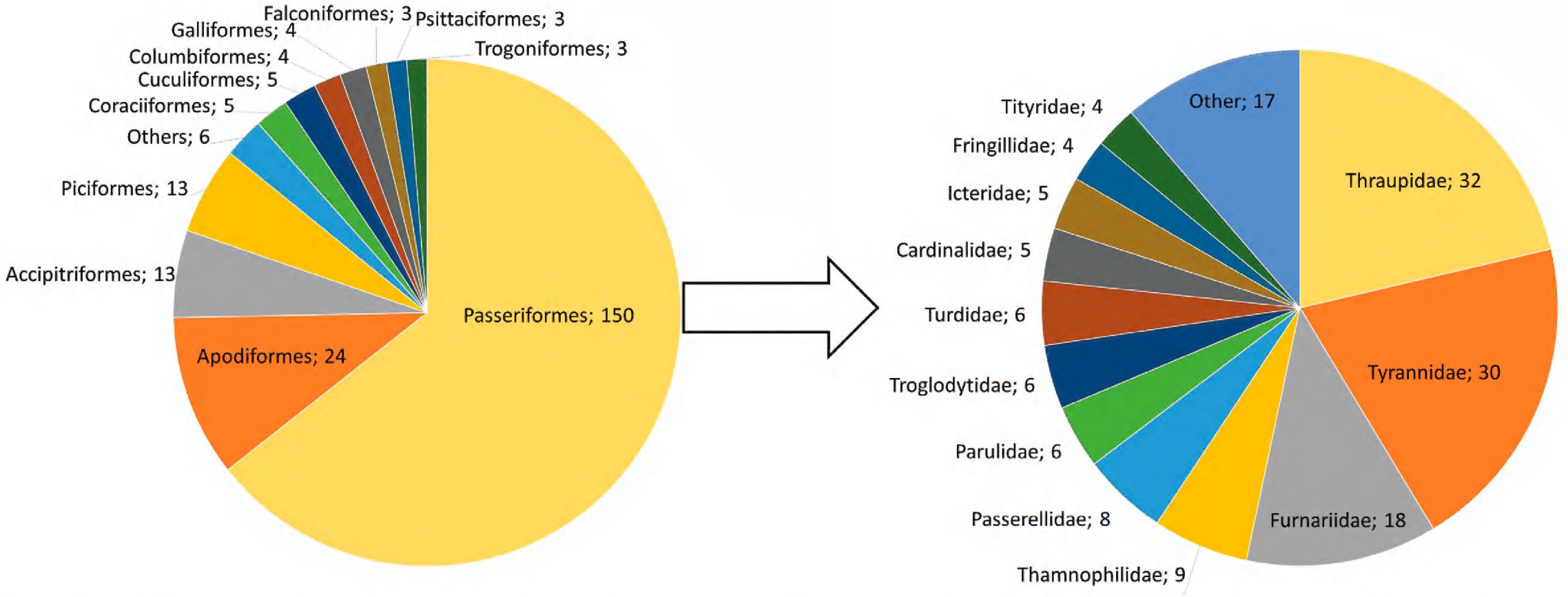


Figure 4. Proportion of the species according to the order, and proportion of species of Passeriformes according to the family in the Buenaventura Reserve, Ecuador. The numbers show the number of species.

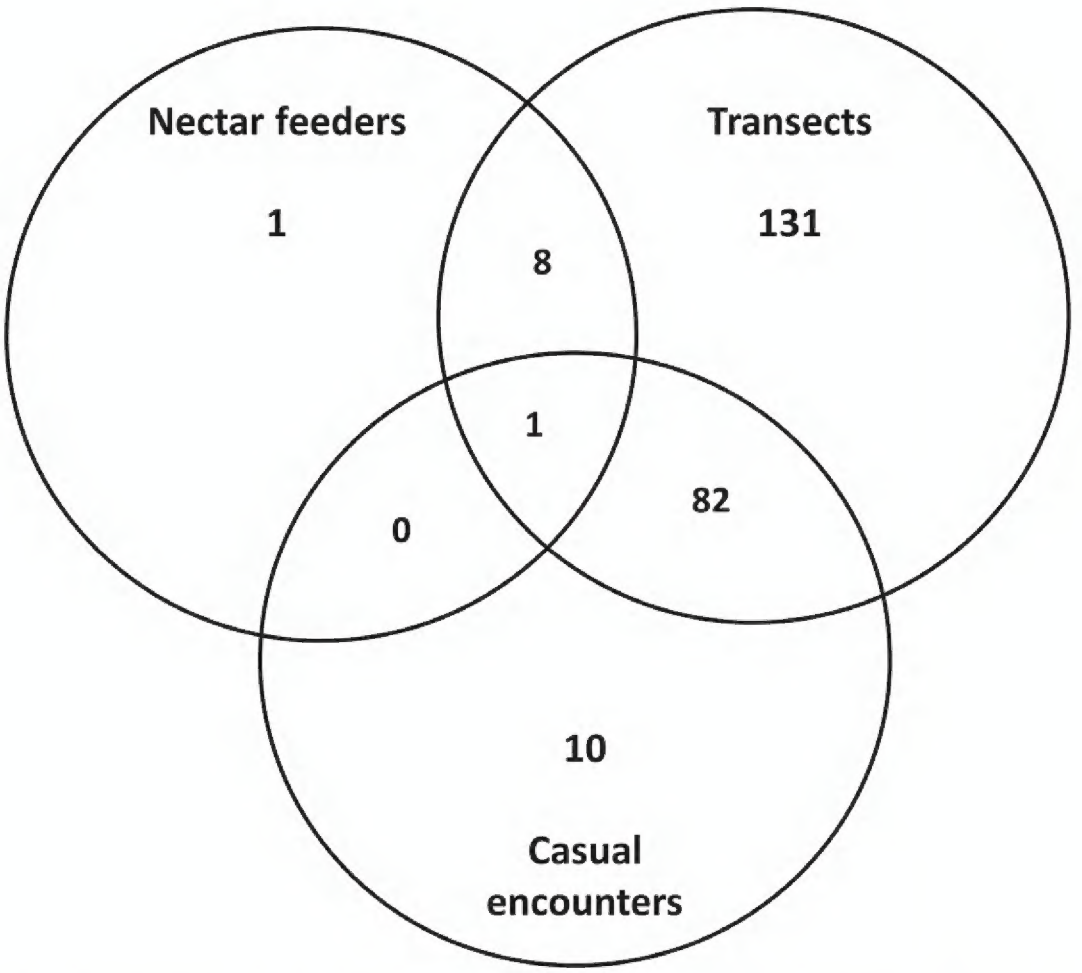


Figure 5. Venn diagram showing the number of bird species registered in the Buenaventura Reserve, Ecuador, according to the methodology employed and its possible combinations.

dangered at a national level, such as the Long-wattled Umbrellabird (*Cephalopterus penduliger*), the Slaty-winged Foliage-gleaner (*Philydor fuscipenne*), and the White-vented Plumeleteer (*Chalybura buffonii*).

Discussion

Our results show that despite the smaller size of PPAs in Western Ecuador (150–10,200 ha), they can harbour a similar number of bird species to larger PAs (up to 243,000 ha) in the same area (Fig. 3). These differences in respect to the size of PAs and PPAs have been also observed in other Latin American countries, such as Costa Rica (Langholz et al. 2000) or Brazil (Pegas and Castley 2014). As our data show, PPAs should not be undervalued because of their smaller size, in agreement with several studies showing that these smaller reserves are important refuges for birds and other vertebrates (e.g. Shanee et al. 2017; Vitorino et al. 2018; Ivanova and Cook 2020). For instance, in our study, we registered 233 different bird species in Buenaventura reserve in 2,300 ha approximately, whereas in Arenillas Ecological Reserve (the closest PA managed by the State) there are 150 bird species in 13,000 ha (Fig. 3). Another remarkable example: there are 270 bird species registered in Machalilla National Park in 60,000 ha, whereas 207 species were registered in Lalo Loor private reserve in only 200 ha (Fig. 3) with similar ecosystems. However, larger protected areas provide additional conservation benefits, such as covering a wider range of environments; they are more likely to support viable populations,

particularly large-bodied species with larger home ranges; they are less sensitive to negative edge effects arising from fragmentation; and rates of species extinction are lower (Cantú-Salazar and Gaston 2010; Durán et al. 2016; Wintle et al. 2019; Cho et al. 2019). Therefore, these small private reserves may have few conservation benefits if they are not connected with larger areas (Pegas and Castley 2014), and they should be integrated into a broader national conservation strategy.

Moreover, the analysis of the trigger species of the six selected IBAs showed that PPAs concentrated a greater number of key species in smaller areas. These results highlight the importance of private reserves for wildlife conservation, and their pivotal role, particularly in under-represented areas and for species with a restricted range (Shanee et al. 2017; Hora et al. 2018). These small private reserves are particularly important in fragmented landscapes for three reasons: i) the creation of large reserves has been prioritised, which has led the potential conservation value of smaller reserves to be dismissed (Volenec and Dobson 2020); ii) the conservation value of the sum of the fragmented patches may be similar to an equivalent area of a large continuous patch (Fahrig 2017; Fahrig et al. 2019); and iii) traditional, larger PAs are often not viable in some priority conservation areas for some reasons (Shanee et al. 2017). In Western Ecuador, where a sizeable proportion of the remaining forests is formed of fragmented patches dispersed within dominant agricultural land uses (Ministerio del Ambiente del Ecuador 2013; Sierra 2013), protecting the best-preserved patches through the creation of private reserves can be considered a suitable conservation tool. Indeed, in a study performed in southern Ecuador, the authors showed that PPAs and the Heritage of Natural Areas of the Ecuadorian State (PANE) attained the same management effectiveness score (López-Rodríguez and Rosado 2017), thus suggesting the feasibility of managing these PPAs in the Ecuadorian context. Moreover, the establishment of PPAs has other advantages in addition to environmental benefits, such as new opportunities for local communities, an increase in the benefits for tourism operators, and a reduction in government costs (Hora et al. 2018).

Our results further show a high diversity of birds in the Buenaventura Reserve, where a high diversity of species, families and orders were observed. The combinations of the three sampling methodologies employed herein can be considered suitable to record most bird species. As Fig. 2 shows, more species could be found by increasing the sampling effort. However, although asymptotes are desired in biodiversity surveys, they are rarely obtained (Lecq et al. 2015), which is relatively frequently in tropical environments with a high diversity. Nevertheless, the use of other methodologies, such as acoustic recordings (Wimmer et al. 2013) or mist-nets, could slightly increase the number of species detected, although the use of mist-nets is invasive.

In Buenaventura, several threatened species and other species with a restricted distribution range were registered. For instance, the Buenaventura Reserve is the only protected area within the distribution range of two endemic and endangered species: El Oro Parakeet (*Pyrrhura orcesi*) and El Oro Tapaculo (*Scytalopus robbinsi*). Both species are endemic to the Tumbes region of Ecuador, whose better-preserved populations are found in this reserve (Vaca et al. 2016; Hermes et al. 2018a, b).

Another remarkable species is the Long-wattled Umbrellabird (*Cephalopterus penduliger*), which is also classified as endangered (EN) in Ecuador owing to habitat loss and poaching (Olmedo 2019). This species has a lek reproductive system, which is one of the main attractions of the reserve as regards bird-watching, being a good example of how private reserves can contribute to preserving certain species of conservation concern, while at the same time favouring local development through bird-watching and ecotourism. Some previous works have shown that NGOs have successfully promoted ecotourism as a local conservation tool (Pegas and Castley 2014; Romero-Brito et al. 2016), and these endangered species could, therefore, be the "flagship" species of the reserve in order to attract tourism with the eventual goal of preserving the forests and their biodiversity.

Finally, climate change is expected to cause negative alterations in evergreen mountain forests, and adapting to these changes will, therefore, require a network of well-conserved areas (Ramirez-Villegas et al. 2014). Moreover, Rodrigues et al. (2014) showed that 50% of the global deterioration of the conservation status of birds and other vertebrates was concentrated in 4% of countries, including Ecuador, mainly because they host one third of the global diversity in these groups of vertebrates. Conservation should, therefore, be focused on these countries. In this scenario and according to our data, PPAs have an extremely important conservation value, protecting many bird species in relatively smaller areas. PPAs can be particularly effective in areas that harbour populations of threatened species and endemic species with a restricted range, and the Buenaventura Reserve fulfils this objective.

Conclusion

In conclusion, when compared to the larger surface of protected areas of the national system managed by the State, private protected areas with a smaller surface can harbour an important number of bird species. Therefore, private reserves are a suitable management tool with which to complement the protected areas managed by the State, thus making it possible to create a greater network of protected areas with high biodiversity that could, in the future, act as the principal areas for an ecological corridor. In this work we have particularly shown that the Buenaventura Reserve, a private reserve managed by an NGO, has a very high number of bird species, some of which are endangered and are rarely recorded in south-western Ecuador, thus highlighting the importance of Buenaventura Reserve with regards to wildlife conservation in south-western Ecuador.

Acknowledgements

The authors are grateful to the Prometeo Project of the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación, Republic of Ecuador for funding this project. We would like to thank the facilities extended by the staff of the Buenaventura Reserve of the Jocotoco Foundation, especially Leovigildo Cabrera, the National University of Loja and the Technical University of Machala. Our thanks also go

to Marina Garrido for her help in preparing the database. José Guerrero-Casado is currently supported by the European Regional Development Fund (ERDF) and the Consejería de Economía, Conocimiento, Empresas y Universidad de la Junta de Andalucía (project reference: 1264483-R).

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Supplementary material 1

Appendix S1

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Data type: table

Explanation note: List of bird species.

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Link: https://doi.org/10.3897/neotropical.16.e63414.suppl1